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FULL LENGTH ARTICLE

Osmo-convective dehydration kinetics of jackfruit (*Artocarpus heterophyllus*)

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KEYWORDS

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Abstract Osmotic dehydration is a process in which partial water is removed by immersion of water containing cellular solid in a concentrated aqueous solution of high osmotic media for a specific time and temperature. Preliminary trials were planned for finalizing the concentration of osmolyte (salt solution: 5%, 10%, 15% and 20%). The osmotically pre-treated samples were dried at 50 °C which were examined using sensory parameters. On the basis of sensory parameters, 15% salt solution concentration was considered best. The osmotically pre-treated jackfruit samples of 15% salt solution were convectively dehydrated in a tray dryer at air temperatures of 50, 60 and 70 °C at constant velocity of 1.5 m/s air flow in perforated trays. Results indicated that drying took place in falling rate period. The sample dried at 60 °C was found better in color as compared to samples at 50 and 70 °C. Mathematical models were fitted to the experimental data and the performance of these models was evaluated by comparing the coefficient of determination (R^2), Root mean square error (RMSE), reduced chi-square (χ^2), percent mean relative deviation modulus (E%) between observed and predicted moisture ratio. The best model was chosen as one with the highest coefficient of correlation (R^2); and the least $\chi^{2,}$ RMSE and mean relative deviation modulus (E). Wang and Singh model, having χ^2 and RMSE value (at 60 °C) of 0.00027 and 0.01655 respectively gave the best results for describing the drying behavior of jackfruit samples.

1. Introduction

Jackfruit commonly known as *Artocarpus heterophyllus* Lam belongs to the family *Moraceae* is a fairly large sized tree and bears the largest fruit among the edible fruits. Jackfruit tree is native to India and popular in several tropical and sub-tropical countries and the fruit is known as the ‘poor man’s fruit’ in eastern and southern parts of India. The seeds are generally eaten in boiled or roasted form or used in many culinary preparations, as it contain similar compositions as

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Nomenclature

$E\%$	mean standard deviation modulus	MR	moisture ratio
M_t	moisture content at time t on db	M_t	moisture content at time t % (db)
$M_{(t+1)}$	moisture content at time $t_{(t+1)}$ on db	n	the number of data points
M_o	initial moisture content on db	R	gas constant (8.314 kJ mol^{-1})
χ^2	reduced chi-square	T	the temperature in °C
$\frac{\delta M}{\delta t}$	instantaneous drying rate (g water/g dm min)	RMSE	root mean square error
t	time (min)	R^2	root mean square error
M_e	Equilibrium moisture content on db		

that of grains. The ripened fruit is normally fibrous and composed of sugars like glucose, fructose, xylose, rhamnose, arabinose and galactose. A single jackfruit seed is enclosed in a white aril encircling a thin brown spermoderm, which covers the fleshy white cotyledon. Jackfruit cotyledons are fairly rich in starch and protein (Swami et al., 2012). Seeds make-up around 10–15% of the total fruit weight (Abedin et al., 2012). India is one of the leading producers of fruits. There is a loss of around 40% per year. The reasons can be attributed to improper post harvest methods, and under utilization of fruits for value added products (Sharma et al., 2013).

In India, the jack seed is an important ingredient in antidote preparation for heavy drinkers. The latex from the bark contains resin which is used sometimes to plug holes in earthen vats and in other products. Jacalin, the major protein from the jack seeds has proved useful tool for the evaluation of immune status of patients infected with HIV. Jackfruit also has been reported to contain antioxidant prenylflavones (Gupta et al., 2011). Nevertheless; it contains no saturated fats or cholesterol, making it one of the healthy fruits to savor. The pulp of the ripe jackfruit may be eaten fresh or incorporated into fruit salad. The seeds are eaten when boiled or roasted (Ejiofor and Owuno, 2013). Jackfruit residue, a by-product of the jackfruit processing industry, represents approximately 2% of the freshly grated meat with a low market value. Upgrading the use of jackfruit residue from animal feed to functional food will be of great benefit to meet the food demands (Feili et al., 2013). The fruit is made of soft, easily digestible flesh (bulbs) with simple sugars like fructose and sucrose. Fresh fruit has small amounts of vitamin-A and flavonoid pigments such as carotene-ß, xanthin, lutein and cryptoxanthin-ß. Together, these compounds play vital roles in antioxidant and vision functions. Fresh fruit is a good source of potassium, magnesium, manganese, and iron.

Drying is an essential process for food industry in order to preserve food quality and food stability by lowering the water activity through decrease in moisture content. Drying as a method of food preservation causes many physical, chemical and biochemical changes in the processed material. The advancement of these changes depends also on the pre-treatment. Pre-treatments quite often proceed with drying of fruit and vegetable in order to minimize the adverse changes occurring during dehydration and subsequent storage. Losses during preparation are also reported to be high, which may sometimes exceed those caused by drying operation. The physical changes affecting dried food quality are shrinkage of cells, loss of rehydration ability, wettability and case hardening. Various chemical changes like pH, soluble sugar, are also reported to occur during drying. On the other hand, the acceptability of dried foods is usually based on the retention of nutritive value and light brown product that can be stored for a long period. Therefore, different pre-treatments are required to maintain the quality of dried foods. Pre-treatments stop the metabolism of cut tissue either by killing cells or by injuring enzymatic routes.

Water elimination is a suitable way to protect foods from spoilage. Indeed, lack of water prevents foods from microorganisms' development. In these conditions, little enzymatic activity is possible and the major part of chemical reactions is slowed down. In order to obtain better protection, practically all water quantity in foods must be carried away. But, it is sometimes advantageous to reduce water quantity (minimizing the energy cost) before drying of foods. In this perspective, osmotic dehydration is one of the methods that can pretreat foods without products structural damages (Zita et al., 2009). In recent years, osmotic dehydration has been widely used for fruits and vegetable preservation due to its potential to keep sensory and nutritional properties similar to fresh fruits and vegetables (Haj et al., 2014). Osmotic dehydration (OD) is one of most important complementary treatment and food preservation technique in the processing of dehydrated foods, since it presents some benefits such as reducing the damage of heat to the flavor, color, inhibiting the browning of enzymes and decrease the energy costs (Khan, 2012). This technology promotes partial removal of water from food by immersion in a concentrated hypertonic solution leaving a material that will need shorter drying times than the original food material, making this process more economical (Fasogbon et al., 2013). Various other benefits of osmotic dehydration include: reducing water removal load, increasing the solid density of the product, and enhancing the textural quality of the product. Moreover, it is one of the least expensive method in which there is minimum loss of color and flavor.

Osmotic dehydration is a useful technique that involves product immersion in a hypertonic aqueous solution leading to a loss of water through the cell membranes of the product and subsequent flow along the inter-cellular space before diffusing into the solution. For fruit dehydration, sucrose solutions with concentrations from 50° to 70° Brix have been used. The osmotic process has received lot of attention as a pre-treatment method in drying as it reduces energy consumption and improves food quality. The osmotic pre-treatment, prior to convective drying is an added complexity to the process design and control, due to the biological tissue change caused by pre-treatment.

The modes involved in convective drying of foods are heat and mass transfer. In convective drying, heat transfer will occur through the flow of heat. Whereas, mass transfer will occur through two mechanisms: Firstly the movement of moisture internally within the foods. Secondly, the movement of water vapor from the food surface as a result of external conditions of temperature, air humidity, air flow and area of exposed surface. One of the most important aspects of drying technology is the modeling of the drying process. Drying is a complex thermal process in which unsteady heat and moisture transfers occur simultaneously. From an engineering point of view, it is important to develop a better understanding of the controlling parameters of this complex process (Darvishi et al., 2013). Mathematical models of the drying processes are used for designing new or improving the existing drying systems or even for the control of the drying process. The drying kinetics of food is a complex phenomenon and requires dependable models to predict drying behavior (Sharma et al., 2003). The most relevant aspects of drying technology are the mathematical modeling of the process and the experimental setup. The modeling is basically based on the design of a set of equations to describe the system as accurately as possible. Drying characteristics of the particular products being dried and simulation models are needed in the design, construction and operation of drying systems. Mathematical modeling is essential to predict and simulate the drying behavior. It is also an important tool in dryer design, contributing for a better understanding of drying mechanism. The thin layer models are widely used for describing the drying process which has been categorized as theoretical, semi-theoretical and empirical models. Empirical models are important not only to describe thin layer water removal, but also to describe the heat penetration during this removal when hot air is used (Silva et al., 2014). The empirical models normally do not possess a theoretical formulation and are usually obtained through simple mathematical analogies based on experimental data and dimensional and statistical analyses. These models frequently present a good fit for the observed data. However, their use is limited due to their dependence on the experimental conditions in which the data were obtained and the characteristics of the material that were used. Theoretical models are based on laws and theories, which are difficult to manage due to their complexity and the involvement of several functions and parameters; these are not convenient for computational practices in most situations. Semi-theoretical models offer a compromise between theory and ease of application. Semi-theoretical models are Lewis, Page, Henderson and Pabis, logarithmic, two term and two term exponential, these models are used widely for designing as well as selection of optimum drying conditions and for accurate prediction of simultaneous heat and mass transfer phenomena during drying process. It also leads to produce the high quality product and increases the energy efficiency of drying system. Thin-layer drying models have been used to describe the drying process of several food products. The principle of modeling is based on having a set of mathematical equations which can satisfactorily explain the system (Garavand et al., 2011).

Generally, the knowledge of the behavior and the determination of the characteristics of drying product are obtained through experimental tests (Ayadi et al., 2014). There are several studies describing the drying behavior of various products. A number of fruits, vegetables and plants are dried for their use in foods and medicines. But the method generally adopted is empirical in nature which requires systematic methodology for adopting a good quality product.

A hybrid technology is particularly advantageous when drying jackfruit because a significant fraction of moisture can be removed non-thermally with simultaneous infusion of desirable solutes. On the other hand, thermal drying after osmotic dehydration is necessary to reduce the moisture content to its final value. But no systematic methodology is reported so far for studying the drying kinetics of osmotically pre-treated jackfruit. Therefore the present study focuses to determine the influence of drying process variables on the osmotic dehydrated jackfruit.

2. Materials and methods

2.1. Procurement of raw material

Jackfruits (commercial variety) were purchased from local market, Sangrur, Punjab, India. First it was peeled which was then further used as a raw material for drying. Shelf life of jackfruit is 4–5 days at 30 °C and 2–6 weeks at 11 °C–13 °C. Initial and final moisture contents of jackfruit cubes were determined by the Standard method (AOAC, 1990).

2.2. Osmotic treatment of jackfruit

The samples were cut into slabs with a uniform thickness. While cutting a jackfruit, very sticky latex is exuded from the rind and fibrous parts of the fruit. The preliminary experiments were planned for finalizing the concentration of osmolyte (salt solution). Different concentrations of salt solutions (5%, 10%, 15% and 20%) were used for the osmotic pre-treatment of samples. Further, the osmotically pre-treated samples were dried at 50 °C which were analyzed using sensory parameters. On the basis of which 15% salt solution concentration was considered the best.

2.3. Drying experiments

The convective-drying of osmotically pre-treated jackfruit samples (15% salt solution) was carried out in a tray dryer at air temperatures of 50, 60 and 70 °C at constant velocity of 1.5 m/s air flow in perforated trays. To follow moisture loss during the drying tests, the product was weighed at the start of the test and then after every 10 min interval and reading was noted down. Similar experiments were performed for each temperature. At the end of each drying experiment, the final moisture content of the samples was determined by using the oven method at 105 °C until it reaches a constant weight. The drying curves (moisture content vs. time) were plotted to observe the effect of process variables and correspondingly drying rate vs. moisture content curves were also plotted.

2.4. Mathematical modeling

Thin layer equations aimed to describe the drying phenomena, have been used to estimate drying times for several products and to access drying curves. Although modeling studies in food drying are important, there is no theoretical model which

Table 1 List of models.

Model name	Model	References
Newton	$MR = \exp(-kt)$	Mujumdar (1987)
Logarithmic	$MR = a\exp(-kt) + c$	Yagcioglu et al. (1999)
Henderson and Pabis	$MR = a\exp(-kt)$	Henderson and Pabis (1961)
Verma et al.	$MR = a\exp(-kt) + (1-a)\exp(-gt)$	Verma et al. (1985)
Magee	$MR = a + kt1/2$	Magee et al. (1983)
Modified page	$MR = \exp(-(kt^n))$	White et al. (1981)
Page	$MR = a\exp(-kt^n)$	Karathanos (1999)
Wang and Singh	$MR = 1 + at + bt^2$	Wang and Singh (1978)

neither is practical nor can it unify the calculations. Therefore the experimental studies prevent their importance in drying and thin layer drying equations are important tools in mathematical modeling of food drying. They are practical and give sufficiently good results. Thin layer modeling of foods describe the drying phenomena in a unified way, regardless of the controlling mechanism. Thin-layer drying models for describing the drying phenomenon of foods are usually based on liquid diffusion theory and the process can be explained by Fick's second law. Several thin layer equations, varying widely in nature, are available in the literature and have been used by many investigators to successfully explain the drying of several agricultural products. The drying kinetics was monitored in terms of evolution of the moisture content along drying, and data were then expressed in terms of the dimensionless variable moisture ratio. The moisture ratio (MR) of jackfruit samples during drying experiments was calculated using the following equations:

$$MR = \left(\frac{M_t - M_e}{M_0 - M_e}\right) \quad (1)$$

where M_t is the moisture content at time t (db), M_o is the initial moisture content (db), and M_e is the equilibrium moisture content (db).

The instantaneous drying rate (DR) of jackfruit samples was calculated from the drying data by estimating the changes in moisture content, which occured in each consecutive time interval and was expressed as g water/g dry matter per minute.

$$\text{Instantaneous drying rate, DR (g water/g dry matter per min)} = \left(\frac{\delta M}{\delta t}\right) = \frac{M_t - M_{t+1}}{t_{t+1} - t_t} \quad (2)$$

2.5. Adequacy of model fitting

To select a suitable model for describing drying process of different jackfruit samples, drying curves were fitted to thin layer drying equations (Table 1). R^2 indicates the proportion of variance that is accounted for by the model. The R^2 value is the quotient of the variances of the fitted values and observed values of the dependent variable. The higher the value of the coefficient of determination, the greater is the success of the mathematical model. In addition to R^2 (coefficient of determination), various statistical parameters such as reduced chi-square (χ^2) and root mean square error (RMSE) were also used as primary criterion to select the best equation. Reduced chi-square (χ^2) is the mean square of the deviations between experimental and predicted values for the models and was used to determine the goodness of fit. The lower the values of reduced chi-square, the better the goodness of fit. RMSE is a measure of the standard error relative of the random component in the estimation. RMSE gives the deviation between the predicted and experimental value which was calculated as follows:

$$\text{RMSE} = \left[\frac{1}{N}\sum_{i=1}^{N}\{\text{MR}_{\exp,i} - \text{MR}_{\text{pre},i}\}^2\right]^{1/2} \quad (3)$$

$$\chi^2 = \sum_{i=1}^{N}\frac{\{\text{MR}_{\exp,i} - MR_{\text{pre},i}\}^2}{N-n} \quad (4)$$

where $\text{MR}_{\exp}$, i is the experimentally observed moisture ratio, MR_{pre}, i is the predicted moisture ratio, N is the number of observations and n is the number of constants.

As these parameters are not a good criterion for evaluating non-linear mathematical models, the percent mean relative deviation modulus (E%) was also used to select the best equation to account for variation in the drying curves of the dried samples as recommended by several authors in their drying studies (Ertekin and Yaldiz, 2004) that indicate the deviation of the observed data from the predicted line. E% is an absolute value which gives a clear idea of the mean divergence of the estimated data from the measured data. Therefore, the best model was chosen as one with the highest coefficient of correlation (R^2); and the least χ^2, RMSE and mean relative deviation modulus (E).

$$E(\%) = \frac{100}{n}\sum_{i=1}^{n}\left|\frac{\text{Experimental Value} - \text{predicted value}}{\text{Experimental value}}\right| \quad (5)$$

The values of E less than 5.0 indicate an excellent fit, while values greater than 10 are indicative of a poor fit.

Table 2 Color characteristics of osmotically pre-treated jackfruit samples at different temperatures.

Temperature (°C)	L^*	a^*	b^*	ΔE
50	71.185	9.404	17.688	49.952
60	60.800	9.166	17.144	40.724
70	58.699	7.553	19.383	40.110

Table 3 Different models and their constants and coefficients at various air temperatures for jackfruit samples.

Model	Temperature (°C)	Constants and coefficients	χ^2	RMSE	R^2	E %
Page	50	k = 0.000345	0.0140	0.117	0.999	92.638
		n = 1.172971				
	60	k = 0.000293	0.005	0.070	0.999	78.595
		n = 1.389773				
	70	k = 0.000345	0.001	0.0322	0.9984	3.460
		n = 1.345677				
Newton	50	k = 0.001228	0.014	0.119	0.999	87.251
	60	k = 0.003021	0.009	0.097	0.997	90.6077
	70	k = 0.0002034	0.016	0.127	0.998	18.664
Modified page	50	k = 0.00225	0.0135	0.116	0.999	92.303
		n = 1.241361				
	60	k = 0.000293	0.004	0.070	0.997	78.594
		n = 1.389773				
	70	k = 0.000481	0.001	0.022	0.9984	3.460
		n = 2.326239				
Henderson and Pabis	50	a = 1.132033	0.011	0.105	0.996	78.804
		k = 0.001523				
	60	a = 1.142079	0.0066	0.0815	0.999	77.408
		k = 0.003560				
	70	a = 1.087318	0.013	0.1177	0.9933	18.579
		k = 0.033266				
Logarithmic	50	a = 45.6788	0.0055	0.0744	0.999	55.3306
		k = 0.000687				
		c = −44.567				
	60	a = 46.7788	0.000498	0.022	0.999	14.995
		k = 0.000745				
		c = −45.567				
	70	a = 48.94462	0.006	0.080	0.997	9.483
		k = 0.000527				
		c = −47.8590				
Magee	50	a = 1.101249	0.0055	0.0735	0.9911	54.175
		k = −0.002317				
	60	a = 1.046126	0.004	0.020	0.998	12.307
		k = −0.004204				
	70	a = 1.085230	0.006	0.080	0.999	9.376
		k = −0.051259				
Wang and Singh	50	a = −0.000169	0.0009	0.0309	0.998	24.717
		b = 0.000001				
	60	a = −0.001595	0.00027	0.01655	0.999	5.4912
		b = −0.000001				
	70	a = −0.004306	0.0026	0.0514	0.999	7.094
		b = −0.000687				

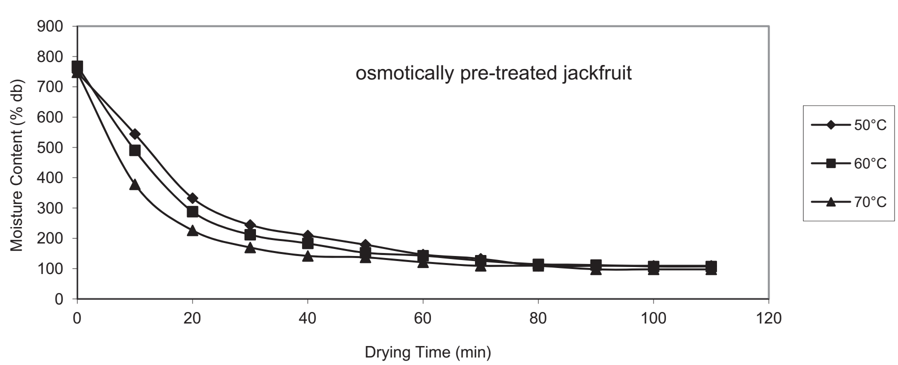

Figure 1 Drying curves of osmotically pre-treated jackfruit samples at different temperatures.

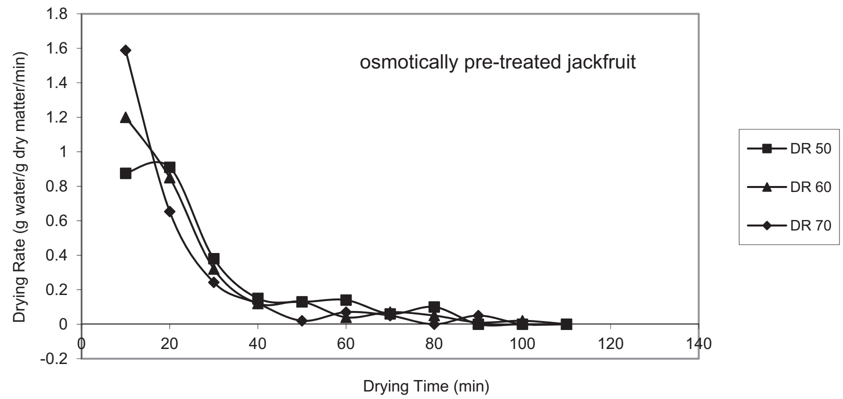

Figure 2 Drying rate versus drying time of osmotically pre-treated jackfruit samples at different temperatures.

2.6. Color evaluation

Color values (L^*, a^*, b^*) of jackfruit samples were obtained using the Hunter colorimeter Model D 25 (Hunter Associates Laboratory Inc., Reston, VA, USA). The instrument was calibrated against a standard red-colored reference tile (L_s = 25.54, a_s = 28.89, b_s = 12.03). Total color difference was calculated by applying the equation:

$$\Delta E = \left\{(L_s - L)^2 + (a_s - a)^2 + (b_s - b)^2\right\}^{1/2} \tag{6}$$

2.7. Rehydration ratio

Rehydration ratio of jackfruit samples was assessed by the method suggested by Jokic et al. (2009). Approximately 3 g of dried sample was placed in a 250 ml laboratory glass beaker (two analyses for each sample), 150 ml distilled water was added and the glass beaker was covered and heated to boil within 3 min. The content of the laboratory glass was then gently boiled for another 10 min and then cooled. The cooled content was filtered for 5 min under vacuum and weighed. The rehydration ratio was calculated as:

$$\mathrm{RR} = Wr/Wd \tag{7}$$

where:
W_r – drained weight (g) of the rehydrated sample.
W_d – weight of the dry sample used for rehydration.

2.8. Statistical analysis

The non-linear regression analysis of the experimental data was carried out by the software STATISTICA, 7.0 for checking the validity of models for all the dehydration processes.

3. Results and discussion

3.1. Color characteristics of jackfruit

The color of the food products is the first attribute that affects the decision of consumer for purchasing or consuming any food products. The results depicted in Table 2 indicate that the increase in temperature affected the color of jackfruit samples. The L^* values for samples at different temperatures varied from 58.699 to 71.185. It was observed that with the increase in temperature from 50 to 70 °C, decrease in L^* was observed in all jackfruit samples. Hunter a^* and b^* values for jackfruit samples ranged from 7.553 to 9.404 and 17.144 to 19.383, respectively. It has been hypothesized that the variation in b^* value among samples may be attributed to the amount of carbohydrate and protein content due to their role in the development of non-enzymatic browning (Jamin and Flores, 1998). ΔE represents the total color difference which decreased with an increase in temperature. The difference in the color characteristics of different samples may be attributed to differences in colored pigments of the samples, which in turn depend on the botanical origin of the plant and also the composition of the sample (Aboubakar et al., 2008). The jackfruit samples dried at 60 °C were found better as compared to sample obtained at 50 and 70 °C in terms of b value. This may be due to the degradation of color which may be at a faster rate at higher temperatures or when exposed to a lower temperature for a longer period of time. However, drying at higher temperature is not suggested due to harmful effects on food components like proteins, vitamins, color etc. The drying time required to reduce the moisture content at any given level was dependent on drying condition being the highest at 50 °C and the lowest at 70 °C (Fig. 2). Therefore, in a practical sense, the samples, obtained at 60 °C were rated better as far as drying and the color characteristics of jackfruit samples are concerned.

3.2. Effect of drying temperature on drying time and drying rate of jackfruit

The moisture content of jackfruit samples as a function of drying time is presented in Fig. 1 for different temperatures (50–70 °C). A number of mechanisms are suggested for controlling the rate of drying. During initial drying, in the constant-rate drying period, water evaporates freely away from the surface. During later periods, water moves from the interior of the product to the surface which may happen due to liquid diffusion, capillary movement, surface diffusion, gaseous diffusion, or may be related to product shrinkage. Drying curves can be determined for a food product in a given dryer and drying conditions, and these will usually show characteristic drying periods, including constant rate drying and falling rate drying

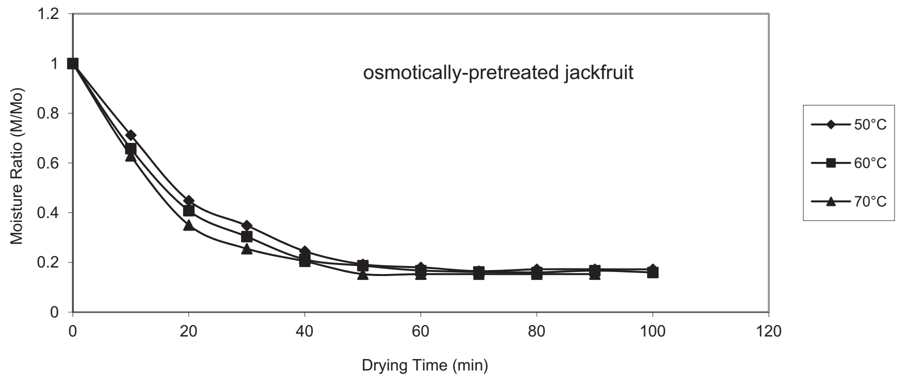

Figure 3 Moisture ratio versus drying time of osmotically pre-treated jackfruit samples at different temperatures.

periods. The moisture content rapidly decreased and then gradual decrease was there with increase in drying time (Fig. 1). The rate of moisture loss was higher at higher temperatures and the total drying time was reduced substantially with the increase in air temperature. However, drying at higher temperature is not suggested due to harmful effects on food components. The drying curve (Fig. 2) indicates that drying rate of different jackfruit samples occurred in falling rate period without occurrence of constant rate during drying. The absence of constant rate convective drying may be due to that the sample could not provide constant supply of water for an appreciable period of time. Arumuganathan et al. (2009) reported the occurrence of only falling rate period during drying of mango slices and milky mushroom. As the temperature was increased from 50 to 70 °C the drying time was decreased. The results indicated that diffusion is the most likely physical mechanism governing moisture movement in the jackfruit samples.

The variations of drying rate and moisture ratio of jackfruit samples with drying time at temperatures of 50, 60 and 70 °C are given in Figs. 2 and 3 respectively. Drying was continued until constant moisture content was reached. Increasing the drying temperature decreased the total drying time since heat transfer increased. Experimental results showed that drying temperature is an effective parameter for the drying of jackfruit samples. It can be seen that at higher moisture content, the increase in temperature has a more considerable effect on the drying rates as compared to lower temperatures, which is almost negligible toward the end (Fig. 2). It was further observed that the drying rate or moisture loss was faster at the beginning. The reduction in drying rate with progression of drying process may be due to the reduction in the available moisture and due to the development of case hardening. Reduction of drying rate might also be due to the development of the shrinkage which causes the reduction in porosity of the jackfruit samples with advancement of the drying process. Premi et al. (2010) also reported the reduction in the drying rate at the end of drying of drumstick leaves due to the reduction in moisture availability with advancement of drying. The reduction in the drying rate at the end of drying may be due to the reduction in moisture content as drying advances. Thus, a higher drying air temperature produced a higher drying rate and consequently the moisture ratio decreased.

In the analysis of thin layer drying data, the moisture ratio (MR) is essential to describe different thin layer drying models. The moisture ratio reduced exponentially as the drying time increased (Doymaz, 2007). Continuous decrease in moisture ratio indicates that diffusion has governed the internal mass transfer. It can be anticipated that moisture ratio (MR) is reduced during drying process at all temperatures investigated in this study but at higher temperature (70 °C) this reduction is quicker (Fig. 3). This can be attributed to a high rate of evaporation from the surface of jackfruit samples at higher temperatures which leads to higher mass transfer rate. A higher drying air temperature decreased the moisture ratio faster due to the increase in air heat supply rate to the jackfruit samples and the acceleration of moisture migration (Demir et al., 2004).

3.3. Validity of various mathematical models for convective drying of jackfruit

The coefficient of correlation and results of statistical analysis are shown in Table 3 for jackfruit samples. Table 3 shows the obtained statistical results of R^2, RMSE, χ^2 and E% for fitting the experimental data to selected drying models in order to determine the best model. All the models presented different values at different temperatures. Furthermore, the highest value of R^2, lowest RMSE, E% and χ^2 values were selected as optimal criteria in order to evaluate the fitting quality of 8 models proposed. In all cases, the R^2 values for the mathematical models were greater than 0.90, indicating a good fit. Generally R^2, RMSE, χ^2 and E% values for jackfruit samples ranged from 0.991 to 0.999, 0.016 to 0.199, 0.0002 to 0.0140, and 3.460 to 92.638 respectively. For jackfruit samples, the highest values of R^2 and lowest values of χ^2, RMSE and E% were obtained with the Wang and Singh model. Therefore, Wang and Singh model can be considered the best model for describing the thin layer drying behavior of osmotically pretreated jackfruit samples dried in a convective type dryer for temperature range, 50–70 °C.

3.4. Rehydration ratio of jackfruit

The rehydration ratio determines the ability of the sample to regain the water without disintegration, which can be taken as a quality parameter. It was observed that with the increase in drying temperature (50–70 °C), the rehydration ratio of jackfruit samples increased (Table 4). The highest rehydration ratio (0.43) was observed in the case of jackfruit samples dried at 50 °C whereas least (0.40) was observed in the case of jackfruit samples dried at 70 °C. This may be due to the fact that a

Table 4 Rehydration ratio of jackfruit samples.

Temperature (°C)	Rehydration ratio
50	0.43
60	0.42
70	0.40

higher drying temperature may cause decrease in water content at a faster rate and brings more physico-chemical changes in the products, which led to decreased rehydration ratio of jackfruit samples. The samples at 60 and 70 °C hardly had any significant difference in the rehydration ratio.

3.5. Conclusions

Preliminary trials were planned for fixing the concentration of osmolyte (salt solution: 5%, 10%, 15% and 20%). The osmolyte concentration, 15% was examined as the best. Drying kinetics in a tray type convective dryer showed an increase in temperature causing reduction in drying time. Drying of jackfruit occurred only in the falling rate period: no constant rate period of drying was observed in the present study. Experimental data were compared with the values predicted by seven thin-layer drying models. Among the models, Wang and Singh model represented the process of drying. Rehydration ratio at 60 °C did not have any significant difference with the sample obtained at 60 °C but was better than the samples obtained at 70 °C. It was observed that with the increase in drying temperature (50–70 °C), the rehydration weight of jackfruit samples decreased. Jackfruit samples used in drying kinetic study when evaluated on the basis of color, L^*, a^*, b^* values and drying time, the temperature of 60 °C was found to be optimum in terms of product quality.

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